**STORMWATER TREATMENT AREA NO. 3 & 4**

**PLAN FORMULATION**

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# 9. PROJECTED TREATMENT PERFORMANCE

## 9.1 INTRODUCTION

This section of the *Plan Formulation Document* (PFD) evaluates the potential range of performance of several STA-3/4 operational scenarios in reducing the concentration of total phosphorus (TP) in discharges to the Everglades Protection Area. This projected performance is measured in terms of the outflow TP concentration of the treatment area. STA-3/4 will be a natural biological treatment system, and will be subject to a wide range of inflow volumes and total phosphorus loads from both the North New River and Miami canals, with the result that projected outflow concentrations can be expected to exhibit wide temporal variations.

Previous research and available data on such systems indicates that the system performance does indeed fluctuate depending on the inflow volumes and loads and overall management strategies for the stormwater treatment area. Thus, this section includes an analysis of three scenarios to reflect these variations. The inflows are adjusted (for each cell) for three operational scenarios:

- All recoverable seepage waters are considered directly discharged (Scenario 1),
- All recoverable seepage waters are returned to the treatment area (Scenario 2), and
- A scenario in which some recoverable seepage waters are returned to the treatment area, with the decision whether or not to return the seepage based on stage in the treatment area interior (Scenario 3).

This analysis further considers potential treatment area performance under varying estimates of the performance of Best Management Practices in the Everglades Agricultural Area in reducing total phosphorus loads delivered to STA-3/4. BMP performance at 25% and 50% TP load reductions are considered. Finally, the analyses are conducted for a range of apparent TP settling rates and background concentrations. A summary of the ranges of k and C* considered in this analysis is presented in Table 9.1.

Table 9.1

Estimated Values for k-C*

| k-C* Scenario | Apparent Settling Rate k (m/yr) | Minimum Wetland Concentration C* (ug/L) |
|---|---|---|
| k1: Minimum (worst) | 10.2 | 3 |
| k2: Expected | 16 | 12 |
| k3: Maximum (best) | 30 | 15 |

Results are presented for both 1965-1995 and 1979-1988 periods, and define the minimum, maximum and expected performance (for both BMP levels) of the overall treatment performance of STA-3/4.

## 9.2 METHOD OF ANALYSIS

The performance of STA-3/4 is based on the k-C* model formulation with atmospheric and groundwater interactions as detailed in Section 3 of the September 1999 *Alternatives Analysis* for STA-3/4. In summary, the model is as follows:

$$(C_2 - C^*)/(C_1 - C^*) = (1 + \alpha/q)^{-r}$$

$$\alpha = (R - ET + I_i - I_o - \Delta S)$$

$$q = Q/A$$

$$\gamma = R - ET + I_i + k$$

$$r = \gamma/\alpha$$

$$C^* = (kC_\lambda + RC_R + I_iC_i)/(\alpha + k + \Delta S + I_o),$$

or $C^* = (kC_\lambda + RC_R + I_iC_i)/\gamma$

where:

$C_1$ = average TP inflow concentration, mg/l

$C_2$ = average TP outflow concentration, mg/l

R = average annual rainfall, m/yr

ET = average annual evapotranspiration, m/yr

$I_i$ = infiltration into the wetland from the groundwater, m/yr

$C_R$ = average TP concentration in rain (wet + dry deposition), mg/l

k = effective TP first-order area-based settling rate, m/yr

A= wetland surface area, $m^2$

Q = average inflow, $m^3$/yr

$q$ = average hydraulic loading rate, m/yr

$I_o$ = infiltration out from the wetland to the groundwater, m/yr

$\Delta S$ = *negative* change in storage, m/yr

$C_\lambda$ = the TP concentration resulting from internal loading by soils and ecological processes, mg/L

$C_i$ = the TP concentration in the upwelling groundwater, mg/L

## 9.3 APPARENT TP SETTLING RATE AND BACKGROUND CONCENTRATION

Projections of treatment performance have been prepared using three separate estimates of the apparent TP settling rate and C* (minimum concentration attainable). Those estimates, summarized earlier in Table 9.1, include:

- The values originally employed in development of the February 15, 1994 *Conceptual Design,* which were based on analysis of data from impacted zones in WCA-2A.
- Values resulting from analysis of data taken from the Everglades Nutrient Removal Project.
- Current estimates considered most representative.

### 9.3.1 Values Taken from the *Conceptual Design*

The apparent TP settling rate presented in the *Conceptual Design* was 10.2 m/yr. No C* value was explicitly stated; the C* value associated with those analyses would be rainfall driven (e.g., $C_\gamma = 0$). For this projection of treatment performance in STA-3/4, those values are considered representative of the probable minimum performance of STA-3/4 in reducing the concentration of total phosphorus in discharges to the Everglades Protection Area. That expectation results from the following comparison of conditions in WCA-2A to those in STA-3/4:

- Inflow loadings to WCA-2A over the period considered in the analysis of that area resulted primarily from regulatory releases through the S-10 structures, with the result that the inflow series was more highly pulsed than is projected for STA-3/4.
- The impacted zone of WCA-2A was not developed as a treatment area; no modifications to topography or flow control were attempted to establish uniform flow conditions in that area. As a result, the overall TP settling rate estimated in WCA-2A resulted from less uniform flow distribution than is established in the design of STA-3/4.
- There were no means for flow redistribution in WCA-2A as is presently provided for in the design of STA-3/4. As was discussed in Section 3 of the September 1999 *Alternatives Analysis* for STA-3/4, provision of means for flow redistribution in the treatment area has been shown to result in improved treatment performance.
- WCA-2A experienced regular dryout during the period over which its performance was evaluated. The settling rate of 10.2 meters per year was developed considering only those periods during which the area was wetted (e.g., with recognition of the wet-period fraction of time), and was adjusted from an earlier estimate of 8 m/yr for that reason. However, that adjustment did not directly take into account the release of sequestered phosphorus following rewetting of the area, for which no data was available.

### 9.3.2 Values Taken from Evaluations of the ENRP

The performance of the ENRP in reducing total phosphorus has been evaluated by the SFWMD and others. Two separate estimates are available. One, taken from Chimney and Moustafa[1], reports an apparent TP settling rate of 18.5 m/yr, again with C* rainfall driven (e.g., $C_\gamma = 0$). A second, reported in Section 3 of the September *1999 Alternatives Analysis* for STA-3/4, estimated the settling rate at 30 m/yr with C* = 15 ppb. As those two estimates were based on the same data, they can be expected to result in similar

[1] "Effectiveness and optimization of stormwater treatment areas for phosphorus removal"; M.J. Chimney and M.Z. Moustafa; in G. Redfield (ed.) *Everglades Interim Report*; South Florida Water Management District; pp. 6-1 to 6-45; 1999

estimates of treatment performance. For this analysis, the settling rate is taken as 30 m/yr, with C* = 15 ppb.

It is anticipated that these values may well overstate the anticipated performance of STA-3/4 in removal of phosphorus, as:

- Inflows to the ENRP over the period analyzed were much more uniform than those projected for STA-3/4, with the result that the anticipated reduction in treatment performance due to pulsing cannot be directly taken from the ENRP operating results.
- The ENRP includes significant areas specifically managed for development of submerged aquatic vegetation in lieu of the emergent macrophytic community presently contemplated for STA-3/4.

### 9.3.3 Current Estimates Considered Most Representative

No widely published or disseminated updates of the evaluation of the ENRP treatment performance have been conducted subsequent to publication of the September 1999 *Alternatives Analysis*. Nonetheless, additional analyses have been undertaken.

For this analysis, estimates prepared in connection with the deliberations of the Advanced Treatment Technology Initiative (ATTI) working group during the summer of 1999 are considered the best estimates currently available. The following is a summary of the basis for those estimates (k = 16 m/yr, C* = 12 ppb)

.

**Preliminary projections of treatment performance presented in that analysis were based on the most current analysis of operating data from the Everglades Nutrient Removal Project (ENRP). However, there does remain concern relative to the degree of transferability of those operating results to final projections of performance in other treatment areas, including STA-3/4.**

That concern arises from the following limitations in the data and analyses conducted to date:

- The ENRP has been operated under inflow conditions (volumes and TP loading) that much more closely approach steady state conditions than is projected for any of the stormwater treatment areas. The influence of increased inflow "pulsing" in the STAs as compared to the ENRP on treatment performance is not presently established, but is fully expected to be considerable.
- Results to date in the ENRP suggest the potential of significant improvement in treatment performance for treatment processes incorporating Submerged Aquatic Vegetation (SAV) in series with emergent macrophyte marshes. However, it is not yet clear that results to date are fully sustainable. Further, long-term operation and maintenance requirements for the SAV communities are not yet well understood.
- The apparent improved performance of the westerly flow path of the ENRP (in which SAV is included as a separate downstream cell) as compared to the easterly flow path (predominantly emergent macrophyte marsh) may be influenced by significant differentials in groundwater inflows and outflows. Those differentials have not been closely examined, and their influence on the ENRP operating results is not well understood.
- Analyses to date suggest the possibility that the relationship between phosphorus concentration in the water column and deposition in the wetland may not truly be a first-order relationship as embodied in the above-described plug flow formula.
- There exist observed areas of significant hydraulic inefficiencies (e.g., poor flow distribution and short-circuiting) in the ENRP. These hydraulic inefficiencies can be expected to negatively influence the treatment performance in the ENRP.

The ENRP includes serial compartmentalization in each flow path, which contributes to improved hydraulic efficiency, thereby leading to improved treatment performance. Cells 1 and 2 of STA-3/4 as presently designed do include serial compartmentalization; Cell 3 incorporates canals situated transverse to the flow path and can be considered as approaching a condition of serial compartmentalization. As a result, the influence of serial compartmentalization in STA-3/4 on treatment performance is expected to parallel that in the ENRP.

Accordingly, this analysis of projected treatment performance in STA-3/4 incorporates a series of adjustments to the observed performance of the ENRP. The nature of those adjustments is at present speculative; the applicability of those adjustments and their values is not known with sufficient certainty to permit full reliance on them, hence the inclusion in this analysis of the previously discussed ranges of the settling rate and background concentration.

**C*:** For projections of treatment performance, **C* is taken as 12 ppb**, applicable to both the emergent macrophyte marsh and the submerged aquatic vegetation.

**K:** Given a C* of 12 ppb, the estimated "best-fit" settling rate to the ENR Project data as a whole has been reported by others as 22.6 m/yr. The current design basis for STA-3/4 varies in certain key respects from that now reflected in the ENR Project. Adjustments to the empirically estimated settling rate in the ENR Project are made through use of a series of factors to reflect the variation between the designs of the ENR Project and STA-3/4.

- The ENR settling rate is multiplied by the factor 1.09 to adjust the effective area of the ENR Project to reflect the presence of non-effective (e.g., non-wetted) lands in the overall treatment area footprint.
- The ENR settling rate is further multiplied by the factor 0.68 to reflect the anticipated influence of pulsed flows on the treatment efficiency in STA-3/4 (a similar number for the ECP as a whole was estimated at 0.61). While the historic flows in the ENR project have been pulsed, the ratio of the maximum rate of flow to the mean rate has been limited to roughly 2.9. In STA-3/4, that ratio is expected to increase to roughly 6.6.

- Finally, the ENR settling rate is further multiplied by the factor 0.96 to "back out" the influence of the SAV community in Cell 4 on the apparent overall treatment efficiency of the ENR Project.

The net effect of all the above factors is to reduce the anticipated effective settling rate for STA-3/4 to 71% of that estimated on the basis of data in the ENR Project. Accordingly, projections of the probable performance of **STA-3/4 given its current design configuration** is based on a settling rate (k) value = 0.71(22.6)= **16.0 m/yr**. Again, that settling rate is associated with a C* value of **12 ppb**, and would be different for any other assigned value for C*.

The actual performance of STA-3/4 may actually exceed that considered in this analysis, given that the ENRP has been demonstrated to contain substantial short circuiting and imbalanced flow distributions. This consideration leads to the anticipation that the estimates presented in this analysis may be somewhat conservative (e.g., potentially overstate outflow concentrations to a presently indeterminate degree).

## 9.4 ESTIMATED TP CONCENTRATIONS FOR WATER BALANCE COMPONENTS

The average TP concentrations in the various components of inflow to STA-3/4 have been updated from previous estimates to reflect the most current information available. Those updated values are taken from a recent SFWMD document[2]. The following is a summary description of those estimates.

- Lake Okeechobee Releases: The TP concentrations considered in this analysis are the 1990-99 flow-weighted mean phosphorus concentration of 66.6 ppb (applied to

[2] "Baseline Data for the Basin-Specific Feasibility Studies to Achieve the Long-Term Water Quality Goals for the Everglades" (ed.); South Florida Water Management District; pp.53; April 2000

Miami Canal Lake releases) and 71.2 ppb (applied to the North New River Canal Lake releases).

- 298 Districts and S-236 Basin: The TP concentrations for the 298 District's runoff and S-236 runoff are taken from the 1994 *Conceptual Design* which applied 100 ppb for Ch. 298 District runoff and 136 ppb for S-236 basin runoff.
- Basin Runoff: The TP concentrations for the North New River and Miami Canal basins' runoff are based on daily regression analyses of historic phosphorus concentration applied to the S-7 and S-8 basins, respectively. That analysis is based on measured concentrations over a period subsequent to implementation of BMPs in the basins, which has been reported to represent a reduction of 50% in discharged TP loads (as compared to pre-BMP conditions). As a result, the estimated TP concentrations resulting from that analysis are considered as associated with a BMP reduction of 50%. The estimated flow-weighted TP concentrations in basin runoff are presented in Table 9.2. It should be noted that the TP concentrations in Table 9.2 vary by year. This represents a significant improvement from previous estimates (including those in the *Alternatives Analysis*), in which a single TP concentration for the entire period of analysis was applied to the runoff from each basin. With this change, it is possible to estimate TP removal performance with full consideration of temporal variations in both hydrologic and total phosphorus loading.
- G-136 Inflows: The TP concentration for inflows to the Miami Canal at G-136 are also based on regression analysis of a variable phosphorus concentration applied to the G-136 inflows. Annual estimates of the TP concentrations in these inflows are also shown in Table 9.2.

Table 9.2

Annual Inflow TP Concentrations

| Year | North New River Runoff Concentration (ppb) | Miami Canal Runoff Concentration (ppb) | Miami Canal: G-136 Concentration (ppb) |
|---|---|---|---|
| 1965 | 84 | 105 | 82 |
| 1966 | 86 | 105 | 85 |
| 1967 | 85 | 104 | 85 |
| 1968 | 85 | 109 | 87 |
| 1969 | 91 | 100 | 81 |
| 1970 | 96 | 91 | 71 |
| 1971 | 86 | 106 | 79 |
| 1972 | 86 | 109 | 72 |
| 1973 | 82 | 103 | 76 |
| 1974 | 81 | 108 | 94 |
| 1975 | 82 | 108 | 88 |
| 1976 | 86 | 103 | 70 |
| 1977 | 93 | 97 | 73 |
| 1978 | 90 | 98 | 76 |
| 1979 | 91 | 96 | 71 |
| 1980 | 90 | 86 | 60 |
| 1981 | 91 | 96 | 66 |
| 1982 | 89 | 111 | 83 |
| 1983 | 101 | 92 | 68 |
| 1984 | 92 | 98 | 69 |
| 1985 | 87 | 99 | 77 |
| 1986 | 93 | 100 | 78 |
| 1987 | 101 | 88 | 68 |
| 1988 | 82 | 100 | 68 |
| 1989 | 79 | 99 | 64 |
| 1990 | 76 | 104 | 67 |
| 1991 | 87 | 95 | 70 |
| 1992 | 91 | 98 | 82 |
| 1993 | 93 | 92 | 84 |
| 1994 | 97 | 93 | 101 |
| 1995 | 83 | 103 | 97 |

In addition to the above-discussed inflows, the analysis of treatment performance must also consider the atmospheric deposition of total phosphorus and the total phosphorus concentration in seepage flows (both for seepage exiting the treatment area and seepage upwelling in the treatment area).

- Atmospheric Deposition: For this analysis, the atmospheric deposition of total phosphorus is taken as equivalent to a concentration of 30 ppb in rainfall.  That value is taken from water quality analyses performed in connection with the *Central and Southern Florida Project, Comprehensive Review Study, Integrated Feasibility Report and Programmatic Environmental Impact Statement*, Jacksonville District U.S. Army Corps of Engineers, 1999.

- TP Concentration in Seepage: The total phosphorus concentration in seepage waters recovered during operation of the Everglades Nutrient Removal Project has consistently been in the range of 20-25 ppb. A value of 25 ppb has been adopted for this analysis, and is applied to both seepage recovered in exterior seepage collection canals and to groundwater upwelling in the treatment area (infiltration). It should be noted that this concentration in seepage waters is reasonably anticipated to exist upon completion of the STA and for an indeterminate period of time thereafter. This relatively low concentration results from the passage of the seepage through the foundation soils; in essence, the foundation soils act to remove phosphorus carried in the seepage. At some (presently undefined) point in the future, it is possible that the removal mechanism in the foundation soils may become "saturated", and that the total phosphorus concentration in seepage waters may approach that in the source of the seepage flow. Monitoring of seepage recovered at the ENRP to date (approaching six years of continuous operation) does not indicate an approach to that "saturated" condition; it is therefore considered reasonable to anticipate similar performance for an extended period at STA-3/4. **The treatment performance projections in this analysis are based upon the assumption that the removal of phosphorus by the interaction of seepage flows with foundation soils will continue for a sufficiently long period of time as to warrant its direct consideration in the analysis.**

Finally, an additional set of basin runoff TP concentrations (by year) were developed for a reduction of TP load in basin runoff of 25%, consistent with the minimum requirements of the EAA Rule (Chapter 40E-63 of the Florida Administrative Code). Those concentrations were estimated by increasing the estimates of the April 2000 *Baseline Data for the Basin-Specific Feasibility Studies to Achieve the Long-Term Water Quality Goals for the Everglades* by a factor of 1.5. That factor represents an adjustment from the District estimates (developed on the basis of a reported BMP performance of 50%) equal to the ratio of (1-0.25)/(1-0.50) = 1.5.

## 9.5 OVERALL BASIN INFLOWS

The inflow volumes from the North New River and Miami canals (e.g., pumped inflows at G-370 and G-372, respectively) are taken from a regional simulation prepared by SFWMD, and are discussed in detail in Section 5 of this *Plan Formulation Document*. When combined with the TP concentrations for the various components of flow described in Section 9.4, the resulting average annual inflow volumes and TP concentrations for North New River and Miami canals are shown in Tables 9.3 and 9.4, respectively. As indicated in Table 9.3, little difference is seen between the 1965-1995 and 1979-1988 inflows for the North New River Canal basin. Although inflow volumes from the Miami Canal basin over those two periods are quite similar, a significant difference does exist in the flow-weighted inflow TP concentration. The flow-weighted inflow concentration is approximately 10 ppb higher during 1965-1995 than during 1979-1988 for a BMP load reduction of 25%; a lesser differential exists for the 50% BMP load reduction.

For all inflows combined, and considering the 25% load reduction due to BMPs, the average annual inflow to STA-3/4 over the period 1965-1995 is estimated to be 645,222 acre-feet per year at a flow-weighted mean TP concentration of 114 ppb. Those values compare favorably with the recommendations of the September 1999 *Alternatives Analysis* (average annual inflow volume of 641,000 acre-feet at a flow-weighted mean inflow concentration of 118 ppb). The average annual inflow TP load to STA-3/4 resulting from this analysis is 97% of that estimated in the *Alternatives Analysis*.

***Here insert Table 9.3***

***Here insert Table 9.4***

For the North New River Canal basin, and considering the 25% load reduction due to BMPs, the average annual inflow to STA-3/4 over the period 1965-1995 is estimated to be 254,928 acre-feet per year at a flow-weighted mean TP concentration of 121 ppb. The recommendations of the September 1999 *Alternatives Analysis* included an average annual inflow volume of 288,200 acre-feet at a flow-weighted mean inflow concentration of 104 ppb.  The average annual inflow TP load to STA-3/4 from the North New River Canal resulting from this analysis is 103% of that estimated in the *Alternatives Analysis*.

For the Miami Canal basin, and considering the 25% load reduction due to BMPs, the average annual inflow to STA-3/4 over the period 1965-1995 is estimated to be 390,294 acre-feet per year at a flow-weighted mean TP concentration of 110 ppb. The recommendations of the September 1999 *Alternatives Analysis* included an average annual inflow volume of 352,800 acre-feet at a flow-weighted mean inflow concentration of 130 ppb.  The average annual inflow TP load to STA-3/4 from the North New River Canal resulting from this analysis is 94% of that estimated in the *Alternatives Analysis*.

The primary variation in the estimates for the two basins is the location at which Lake Okeechobee releases are assigned.  **As recommended in Section 3 of this *Plan Formulation Document*, Lake releases are considered in this analysis as made to the Miami Canal to the maximum practicable extent; this preferred point of discharge should be established as an operational requirement in any subsequent operations plan for STA-3/4.** This point of release is selected due to the slightly lower (roughly 5 ppb) anticipated total phosphorus concentration at that location as compared to the North New River canal. An average annual volume of 49,909 acre-feet in North New River Canal basin BMP makeup flows are shifted to the Miami Canal.

## 9.6  ALTERNATIVE OPERATIONAL SCENARIOS AND ADJUSTED INFLOWS

Section 7 of this *Plan Formulation Document* presents the results of long-term hydrologic simulations of the operation of STA-3/4 under three separate seepage management scenarios. The results of those simulations vary in both the quantity of seepage water (and associated TP load) returned to the treatment area from the perimeter seepage collection canals, and in the quantity and associated TP load in supplemental releases from Lake Okeechobee necessary to prevent dryout of the treatment area. A basic description of those seepage management scenarios is included in the introductory paragraph of this Section 7. It is necessary to adjust the above-discussed inflows to the various cells of STA-3/4 to reflect modifications to the overall water balance resulting from the detailed hydrologic simulation of STA-3/4. Those adjustments are necessary so that the subsequent projections of treatment performance are based on a full accounting of all water balance components.

Figure 9.1 consists of a schematic diagram showing the various adjustments to inflow made for the three operating scenarios. The adjusted inflows are then used to define the inflow volumes and TP concentrations for use in treatment performance projections.

***Here insert Figure 9.1***

The following paragraphs provide additional information on the various inflow adjustments.

### 9.6.1 Supplemental Flows

Supplemental flows are those flows necessary to maintain a minimum depth of roughly 6 inches in the treatment area cells. These inflows were developed from the simulations discussed in Part 7, and were not included in the District-furnished (base) inflow data. As a result, these flows are in every instance added to the base inflow data. TP concentrations in these additional inflows are assigned dependent upon their point of withdrawal from Lake Okeechobee as discussed in 9.4 (71.2 ppb for releases to the North New River Canal, and 66.6 ppb for releases to the Miami Canal).

### 9.6.2 Supply Canal Seepage

The Supply Canal from G-372 to the northwest corner of STA-3/4 parallels the perimeter of the Holey Land Wildlife Management Area, and does not abut the treatment area itself. Accordingly, all estimated seepage losses from the Supply Canal (and their associated phosphorus load) are <u>deducted</u> from inflows to Cells 2 and 3 under each of the three operational scenarios. This includes seepage from the Supply Canal to the Holey Land; deep seepage from the Supply Canal to the north; and seepage recovered in the seepage collection canal.

Under Scenario 2, all seepage recovered in the seepage collection canal along and adjacent to the Supply Canal is then added to Cells 2 and 3 inflows, at a TP concentration of 25 ppb.

Under Scenario 3, a part of the seepage recovered in the seepage collection canal along and adjacent to the Supply Canal is added to Cells 2 and 3 inflows, dependent upon stage in the treatment cells and to the extent defined in Section 7 of this *Plan Formulation Document.* Those additional inflows are assigned a TP concentration of 25 ppb.

### 9.6.3 Seepage Along the North Boundary of the Treatment Area

There are two primary components of seepage along the north boundary of the treatment area. The first component is deep seepage, passing beneath the seepage collection canal and irretrievably “lost” to the north. These volumes (and their associated phosphorus loads) are considered to have entered the treatment area cells, and <u>no adjustment to inflows are made therefore.</u>

The second component is seepage recovered in the seepage collection canal along and adjacent to the inflow canal. These volumes (and their associated phosphorus loads) are deducted from the estimated inflows to each cell. Under Scenario No. 1, no further adjustment is made, as those flows are considered directly discharged.

Under Scenario No. 2, in which all recovered seepage is returned to the treatment area, those volumes are then added back to the inflow volumes, at a TP concentration of 25 ppb. The net effect under Scenario No. 2 is to neither increase nor decrease total inflow volumes, but to reduce inflow total phosphorus loads by the difference between the surface water TP concentration and the 25 ppb concentration assigned to recovered seepage.

Under Scenario 3, a part of the seepage recovered in the seepage collection canal along and adjacent to the Inflow Canal is added to the treatment area inflows, dependent upon stage in the treatment cells and to the extent defined in Section 7 of this *Plan Formulation Document.* Those additional inflows are assigned a TP concentration of 25 ppb.

Under both Scenarios 2 and 3, recovered seepage returned to the treatment area is assigned as additional inflow to Cell 1. This assignment results from the anticipated split in seepage collection canal flows between flows delivered to G-370 and flows delivered to G-372. The point of flow division in the seepage collection canal is anticipated to approximate the point of connection between the Supply Canal and the Inflow Canal at the northwesterly corner of the treatment area. The result is that recovered seepage along the Supply Canal is considered delivered to G-372 and then returned to Cells 2 and 3; seepage recovered along the Inflow Canal is considered delivered to G-370 and then returned to Cell 1.

### 9.6.4 Seepage Along the East Boundary of the Treatment Area

All seepage exiting along the east boundary of the treatment area (e.g., along the East Perimeter Levee adjacent to Cell 1) is considered to have first entered the treatment area, and no adjustment to inflows are made therefore. This includes both deep seepage, and seepage recovered in the seepage collection canal along the East Perimeter Levee.

Under Scenario No. 2, all seepage recovered in the seepage collection canal is considered returned to the treatment area (Cell 1) at an average TP concentration of 25 ppb, and is added to the Cell 1 inflows. Under Scenario No. 3, a part of the seepage recovered in the seepage collection canal (to the extent identified in Section 7 of this *Plan Formulation Document*) is considered returned to the treatment area (Cell 1) and is added to Cell 1 inflows. Those additional inflows are assigned a TP concentration of 25 ppb.

### 9.6.5 Adjusted Treatment Area Inflows

Annual summaries of adjusted inflows to Cell 1 from the North New River Canal basin via Pumping Station G-370 are presented in Table 9.5 (Scenario No. 1), Table 9.6 (Scenario No. 2) and Table 9.7 (Scenario No. 3).

Annual summaries of adjusted inflows to Cells 2 and 3 from the Miami Canal basin via Pumping Station G-372 are presented in Table 9.8 (Scenario No. 1), Table 9.9 (Scenario No. 2) and Table 9.10 (Scenario No. 3). Those inflows are assigned to the two cells on the basis of relative area.

***Here insert Table 9.5***

***Here insert Table 9.6***

***Here insert Table 9.7***

***Here insert Table 9.8***

***Here insert Table 9.9***

***Here insert Table 9.10***

## 9.7 TREATMENT PERFORMANCE PROJECTIONS

The projected performance of STA-3/4 in reducing the level of total phosphorus in discharges to the Everglades Protection Area has been evaluated employing:

- The adjusted inflow volumes and flow-weighted inflow concentrations discussed under 9.6. The analyses consider both a 25% reduction in TP loads carried in runoff from the EAA due to the implementation of BMPs (as required under Chapter 40E63 FAC), and a 50% reduction in TP loads (reflecting actual performance of the BMP program to date).
- The estimated cell seepage losses, cell seepage inflows, precipitation, and rainfall defined in Section 7 of this Plan Formulation Document, with TP concentrations associated with those components as defined in 9.4.
- The analytical methodology presented in 9.2, using the range of settling rates and background concentrations presented in 9.3.

Analyses have been prepared for each of the three operational scenarios, and are summarized in the form of series of tables in which the projected flow-weighted mean outflow concentrations are identified for each year over the period 1965-1995. The computations are performed on an annual basis.

It should be noted that the k-C* parameters were empirically developed from data aggregated over a multiple of years, with the result that application of those parameters to time series as short as one year may not be entirely consistent with the basis for the parameter estimates. Accordingly, additional analyses were prepared in which the various inflows, precipitation, rainfall, and seepage inflows and outflows are averaged over the 1965-1995 and 1979-1988 periods, and a long-term average outflow concentration computed for comparison to the annual estimates.

Each tabulation summarizes the annual maximum, annual minimum, and estimated annual average (computed simply as the arithmetic average of all annual values without flow-weighting) discharge concentrations. In addition, a flow-weighted average is reported, in which the annual estimates of outflow concentration are flow-weighted for each of the two periods considered (1965-1995 and 1979-1988). Finally, the estimated flow-weighted mean outflow concentration computed aggregating all years of the two periods and computing a single average annual outflow concentration is presented ("POR Ave").

The treatment performance projections tabulated in this section 9.7 consider only direct discharges from the treatment area to the L-5 Borrow Canal. Volumes and TP loads associated with the direct discharge of recoverable seepage (Scenarios 1 and 3) are excluded from those tabulations.

### 9.7.1 Projected Treatment Performance, Scenario No. 1

The projected treatment performance of Cells 1, 2 and 3 under operational scenario no. 1 (all recoverable seepage directly discharged, no return to the treatment area) is presented in Tables 9.11, 9.12 and 9.13, respectively.

The aggregate treatment performance of STA-3/4 as a whole, in which the results for the three cells are composited, is presented in Table 9.14. Figure 9.2 presents a graphical summary of the projected operation of STA-3/4 under Scenario No. 1, and shows (by year for each of the 31 years simulated):

- Flow-weighted inflow concentration to each of the three cells.
- Flow-weighted outflow concentration for STA-3/4 as a whole.
- Volume discharged to the L-5 Borrow Canal.

The information presented in Figure 9.2 is for a reduction of TP loads discharged from the EAA of 25% as required by Chapter 40E-63 FAC.

***Here insert Table 9.11***

***Here insert Table 9.12***

***Here insert Table 9.13***

***Here insert Table 9.14***

***Here insert Figure 9.2***

### 9.7.2 Projected Treatment Performance, Scenario No. 2

The projected treatment performance of Cells 1, 2 and 3 under operational scenario no. 2 (all recoverable seepage returned to the treatment area, with no direct discharge of those flows) is presented in Tables 9.15, 9.16 and 9.17, respectively.

The aggregate treatment performance of STA-3/4 as a whole, in which the results for the three cells are composited, is presented in Table 9.18. Figure 9.3 presents a graphical summary of the projected operation of STA-3/4 under Scenario No. 2, and shows (by year for each of the 31 years simulated):

- Flow-weighted inflow concentration to each of the three cells.
- Flow-weighted outflow concentration for STA-3/4 as a whole.
- Volume discharged to the L-5 Borrow Canal.

The information presented in Figure 9.3 is for a reduction of TP loads discharged from the EAA of 25% as required by Chapter 40E-63 FAC.

***Here insert Table 9.15***

***Here insert Table 9.16***

***Here insert Table 9.17***

***Here insert Table 9.18***

***Here insert Figure 9.3***

### 9.7.3 Projected Treatment Performance, Scenario No. 3

The projected treatment performance of Cells 1, 2 and 3 under operational scenario no. 3 (recoverable seepage returned to the treatment area dependent on cell stage, with direct discharge of remaining seepage flows) is presented in Tables 9.19, 9.20 and 9.21, respectively.

The aggregate treatment performance of STA-3/4 as a whole, in which the results for the three cells are composited, is presented in Table 9.22. Figure 9.4 presents a graphical summary of the projected operation of STA-3/4 under Scenario No. 3, and shows (by year for each of the 31 years simulated):

- Flow-weighted inflow concentration to each of the three cells.
- Flow-weighted outflow concentration for STA-3/4 as a whole.
- Volume discharged to the L-5 Borrow Canal.

The information presented in Figure 9.4 is for a reduction of TP loads discharged from the EAA of 25% as required by Chapter 40E-63 FAC.

***Here insert Table 9.19***

***Here insert Table 9.20***

***Here insert Table 9.21***

***Here insert Table 9.22***

***Here insert Figure 9.4***

## 9.8 EVALUATION OF RESULTS

This section presents an evaluation of the performance of STA-3/4 under each of the three operational scenarios. This evaluation considers:

- The relative performance of the treatment area under the three scenarios, considering only the flow-weighted concentration in direct discharges to the L-5 Borrow Canal, together with the apparent capacity of STA-3/4 to comply with probable operating permit requirements.
- The absolute magnitude of estimated TP loads discharged to the Everglades Protection Area, considering both surface discharges to the L-5 Borrow and the direct discharge of recoverable seepage.

### 9.8.1 Relative Performance Under The Various Operating Scenarios

No permit governing the operation of STA-3/4 has yet been drafted. This evaluation is based on the compliance tests established in operating permits issued by the Florida Department of Environmental Protection for the operation of STA-1W, STA-2, STA-5, and STA-6. Those compliance tests may be simply stated as:

- Flow-weighted discharge concentration not exceeding 76 ppb in any given year.
- Flow-weighted discharge concentration not exceeding 50 ppb in two of any three years.

A "side-by-side" comparison of the computed outflows for each scenario under the full range of k-C* parameters considered is presented in Table 9.23. In no instance does any flow-weighted annual outflow concentration exceed 76 ppb. Periods during which the flow-weighted annual outflow concentration in any two years of three exceed 50 ppb are shaded to facilitate ready identification.

***Here insert Table 9.23***

Given the results summarized in Table 9.23, there is a high degree of confidence that the treatment performance of STA-3/4 will be capable of meeting probable operating permit requirements for total phosphorus discharge, if established consistent with the requirements in permits issued for other stormwater treatment areas. The maximum annual flow-weighted mean discharge concentration computed under any of the analyses performed is 62 ppb, well below the (presumed) permit limitation of 76 ppb in any given year.

Only under the assumption of a BMP reduction percentage of 25% and the use of a settling rate of 10.2 m/yr do mean annual concentrations exceed 50 ppb in two of any three years. Under each of the three operating scenarios considered, an annual mean concentration of 50 ppb would have been exceeded in each of the three years 1968-1970; in addition, the 50 ppb value would have been exceeded in 1966. In essence, for each of the three scenarios, the STA would have been considered out of compliance over the period 1966-1971. As discussed in 9.3, that settling rate of 10.2 m/yr is considered to represent a very conservative estimate of performance in STA-3/4.

As previously discussed, the settling rate of 16 m/yr and a background concentration of 12 ppb are considered the best estimates presently available but still potentially conservative. For those values, an annual mean discharge concentration of 50 ppb would have been reached (but not exceeded) in but one year (1969) for each of the scenarios, and then only for the minimum BMP reduction of 25%.

Inspection of the computed outflow concentration by cell indicates that, for any given combination of k-C*, BMP performance and operational scenario, the projected performance of cells 2 and 3 (which are very similar) exceeds that of Cell 1. Computed outflow concentrations from Cell 1 generally range from 3 to 10 ppb higher than from Cells 2 and 3. It is apparent that Cell 1 is loaded to a greater degree than Cells 2 and 3. This disproportionate loading results from:

- A reduction in the hydraulic and nutrient load discharged to Cells 2 and 3 due to seepage losses between pumping station G-372 and the treatment area.
- An unbalanced impact due to seepage return, as all recoverable seepage captured along the north boundary of all three cells is returned to Cell 1.
- The estimated mean TP concentration in runoff from the S-7/S-2 (North New River Canal) Basin considered in this analysis is higher than that of previous estimates. Conversely, the estimated mean TP concentration in runoff from the S-8/S-3 (Miami Canal) Basin considered in this analysis is lower than that of previous estimates.

Further adjustment of the internal configuration of STA-3/4 to more equally balance projected loading by increasing the size of Cell 1(and commensurately reducing the sizes of Cells 2 and 3) is not recommended. There exists a significant degree of uncertainty and imprecision in the overall inflow load and distribution by cell. Attempts to fully balance influent loading on a predictive basis cannot be expected to fully succeed; the distribution will vary from year to year, and will be influenced by a wide variety of factors not capable of being controlled. Such a redistribution of the internal area of STA-3/4 would not be expected to markedly affect or influence overall treatment performance, but would be expected to lead to difficulties with the hydraulic design and performance of Cells 2 and 3. However, the potential for unbalanced performance of the STA underscores the desirability of Structures G-382A, G-382B, and G-383, which provide the capacity for the transfer of some flows from Cell 1 to Cells 2 and 3.

A significant conclusion that can be reached on the basis of the analyses performed is that operation of STA-3/4 under any of the three scenarios considered will have little influence on the overall concentration of total phosphorus in discharges to the L-5 Borrow Canal. The differential in the long-term mean outflow concentrations generally ranges from 1 to 2 ppb.

Finally, it should be noted that the analyses presented herein have largely been conducted on an annual basis, and long-term performance estimated by averaging the annual estimates. Computation of long-term mean outflow concentrations on the basis of averaged inflow volumes and loads would typically result in a lower concentration than would be estimated by averaging annual estimates. As indicated in Table 9.23, that differential generally ranges from 2-4 ppb. As the analytical parameters employed in the analyses were developed from data sets having durations greater than one year, it can be reasonably postulated that actual outflow concentrations by year may be slightly lower than reported herein. This postulate is consistent with observations that the apparent settling rate may to a degree be dependent upon the concentration of total phosphorus in the water column (e.g., as concentrations increase, the settling rate appears to increase). On that basis, it is anticipated that overstatements in the computed outflow concentrations may be greatest during years of high flow and high influent concentration.

### 9.8.2 Aggregate TP Loads Discharged to the Everglades Protection Area

To this point, the analysis has considered only direct discharges of surface water from STA-3/4 to the L-5 Borrow Canal. Table 9.24 presents a summary of the average annual TP load discharged from the STA-3/4 facilities, considering both surface water discharges to the L-5 Borrow Canal and the direct discharge of recoverable seepage (at an average concentration of 25 ppb).

Total discharge volumes vary but slightly between Scenarios 2 and 3, but do increase for Scenario 1. However, since that increase results primarily from the introduction of additional supplemental water supply, it is not considered an advantage.

It is seen that, when total (e.g., blend of discharges to L-5 through the STA-3/4 outflow control structures and direct discharge of seepage) discharges are considered, flow-weighted mean total phosphorus concentrations do vary between the three alternatives to a greater degree than when considering outflow structure discharges alone. This results from the influence of directly discharged seepage at an assigned concentration of 25 ppb, as that is somewhat below the estimated concentration in outflow structure discharges. As a result of those higher flow-weighted mean concentrations, the total phosphorus load discharged to the EPA would be higher under Scenario 2 (in which no seepage is directly discharged) than under Scenarios 1 and 3.

Table 9.24

Aggregate TP Loads Discharged to EPA (Including Seepage)

| | Units | Ave Annual Discharge | Flow-weighted TP Concentrations/Loads | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | BMP 25% | | | BMP 50% | | |
| | | | k=10.2 c*=3 | k=16 c*=12 | k=30 c*=15 | k=10.2 c*=3 | k=16 c*=12 | k=30 c*=15 |
| Scenario #1 | | | | | | | | |
| 1965-1995 | | | | | | | | |
| Ave Annual Discharge | (acre-ft) | 565,902 | | | | | | |
| TP Concentration | (ppb) | | 41 | 29 | 18 | 28 | 23 | 17 |
| Ave Annual TP Load | (tonne) | | 29 | 20 | 13 | 20 | 16 | 12 |
| 1979-1988 | | | | | | | | |
| Ave Annual Discharge | (acre-ft) | 553,526 | | | | | | |
| TP Concentration | (ppb) | | 39 | 27 | 18 | 27 | 23 | 16 |
| Ave Annual TP Load | (tonne) | | 26 | 18 | 12 | 18 | 16 | 11 |
| Scenario #2 | | | | | | | | |
| 1965-1995 | | | | | | | | |
| Ave Annual Discharge | (acre-ft) | 544,776 | | | | | | |
| TP Concentration | (ppb) | | 44 | 35 | 23 | 34 | 29 | 21 |
| Ave Annual TP Load | (tonne) | | 29 | 24 | 15 | 23 | 19 | 14 |
| 1979-1988 | | | | | | | | |
| Ave Annual Discharge | (acre-ft) | 532,125 | | | | | | |
| TP Concentration | (ppb) | | 41 | 33 | 22 | 33 | 28 | 20 |
| Ave Annual TP Load | (tonne) | | 27 | 22 | 15 | 21 | 18 | 13 |
| Scenario #3 | | | | | | | | |
| 1965-1995 | | | | | | | | |
| Ave Annual Discharge | (acre-ft) | 551,856 | | | | | | |
| TP Concentration | (ppb) | | 42 | 30 | 19 | 29 | 24 | 18 |
| Ave Annual TP Load | (tonne) | | 28 | 20 | 13 | 20 | 17 | 12 |
| 1979-1988 | | | | | | | | |
| Ave Annual Discharge | (acre-ft) | 539,374 | | | | | | |
| TP Concentration | (ppb) | | 39 | 28 | 19 | 28 | 24 | 17 |
| Ave Annual TP Load | (tonne) | | 26 | 19 | 12 | 19 | 16 | 11 |

The apparent advantage (in which phosphorus loads discharged reduce with increasing volumes of directly discharged seepage) under Alternative 1 would be expected upon initial operation of the STA, and for an indeterminate period thereafter. As water quality improvement resulting from the passage of the seepage flows through the foundation soils reduces in the future (see 9.3), that advantage would reduce. After a sufficient period of time, the advantage would disappear altogether. The time required for that to occur cannot presently be predicted. However, it is clear that, once Phase 2 technology is implemented and the target outflow concentration is reduced (presumed value of 10 ppb), it would be necessary to cease direct discharge of recovered seepage, as it would not meet that standard. The apparent advantage of Scenario 1 (and, to a lesser extent, Scenario 3) in reducing total phosphorus loads discharged must be considered temporary.

## 9.9 RECOMMENDATIONS

On the basis of the analyses reported herein, it is concluded that:

- STA-3/4 can be expected, with a high degree of confidence, to meet operating permit requirements relative to the discharge of total phosphorus that have been applied to previously completed stormwater treatment areas.
- The best current estimate of the long-term flow-weighted mean concentration of total phosphorus in discharges from the STA-3/4 outflow control structures ranges from 35 ppb (for a BMP performance of 25%) to 29 ppb (for a BMP performance of 50%). Those values are reported for operational scenario no. 2, and would be slightly lower for scenarios 1 and 3.
- Computed discharge concentrations at the STA-3/4 outflow control structures are not sensitive to variations in the degree to which recovered seepage is returned to the treatment area.
- The total phosphorus load discharged to the EPA is somewhat more sensitive to seepage management operations, with an advantage identified to the direct discharge of recovered seepage. However, that advantage is considered temporary, and would in any event be expected to no longer exist once Phase 2 standards must be met. The Everglades Forever Act establishes a date of December 31, 2006 for that event, with the result that the advantage to the direct discharge of seepage would at best exist over roughly a 3-year period. In addition, the substantial direct discharge of recovered seepage is shown to result in increased reliance on the regional system for supplemental water to prevent dryout of the treatment area.

On the basis of the above conclusions, it is recommended that:

1. The design of STA-3/4 be developed to permit the reintroduction of recovered seepage to the treatment area under any operational condition.

2. Substantial expenditures to further develop the design of STA-3/4 to permit the operational flexibility for direct discharge of recovered seepage do not appear warranted.

Given the above, it is further recommended that the preliminary design presented herein and graphically presented on the various plates included in Section 1 of this *Plan Formulation* be further modified during detailed design to:

3. Not include provisions for the direct discharge of seepage recovered at Pumping Station G-372 to the Miami Canal downstream of Structure G-373. In lieu thereof, and in accordance with the recommendations contained in Section 10 of this *Plan Formulation*, it is recommended that the design of G-372 include provisions to permit the discharge of recovered seepage to either the Supply Canal or directly to the Holey Land Wildlife Management Area at the District's discretion.
4. Not include provisions for the direct discharge of seepage recovered at Pumping Station G-370 to the East Seepage Canal and from that point to the Discharge Canal. All recovered seepage at G-370 should be returned to the Inflow Canal. In connection with this recommendation, Structure G-384A would no longer be required, and there would be no need for the addition of an operable gate at (existing) Structure G-384B. Adoption of this recommendation will also permit, subject to the concurrence of the Florida Department of Transportation, the elimination of the East Perimeter Levee (replaced with enlargement of an existing FDOT berm along the west right-of-way of U.S. Highway 27) and adjacent seepage collection canal. The alternative design cross section at this location is shown on Plate 12 in Section 1 of this *Plan Formulation*.